~~SPECIFICATION~~

A Corrosion-Resistant Metal Made Sensor for Fluid

and

A Fluid Supply Device for which The Sensor Is Employed

[0000] This is a National Phase Application in the United States of International Patent Application No. PCT/JP2005/000266 filed January 13, 2005, which claims priority on Japanese Patent Application No. 2004-047701, filed February 24, 2004. The entire disclosures of the above patent applications are hereby incorporated by reference.

Field of the Invention

[0001] The present invention is employed mainly for detecting a mass flow rate and/or pressure in a gas supply line, and the like, employed in~~with~~ semiconductor manufacturing facilities, and is concerned with a corrosion-resistant metal made sensor for fluid, and a fluid supply device for which the sensor is employed, in~~of~~ which all of the gas contacting faces are formed of corrosion-resistant metals, such as stainless steel (SUS316L) and the like, having excellent corrosion resistance even to highly corrosive fluids. T~~,~~ thus, the corrosion-resistant metal made sensor can be made~~enabling to achieve to make it~~ particle-free and leak-free, and further ~~to~~ enhanced with respect to~~the~~ detecting accuracy.

Background of the Invention

[0002] Conventionally, a capillary thermal-~~-~~type mass flow rate sensor, or a silicon-made ultra-small sized thermal-~~-~~type mass flow rate sensor, for which micro-machine technologies have been employed, has been widely used to measure a mass flow rate of fluid in various technologies~~the technical fields~~, such as in~~the~~ chemical analysis equipment and the like.

The former, or ~~the~~ capillary thermal-~~-~~type mass flow rate sensor, is characterized by the fact that the sensor has~~allows~~ its gas contacting faces ~~of the sensor to~~

~~-1-~~

~~be~~ made of stainless steel due to~~because of~~ its structure, which ~~thus enabling to~~ enhances the~~its~~ corrosion resistance of the sensor to fluids that it~~to be~~ measures ~~at ease~~.

[0003] Also~~However~~, the capillary thermal-~~-~~type mass flow sensor must~~is required to~~ be equipped with a resistance wire for a heater that is~~to be~~ wound to heat a capillary tube, which causes~~thus causing~~ a problem that leads~~might lead~~ to unevenness in property among ~~he~~ products.

Another problem is~~may be~~ that the response speed of the~~a~~ mass flow rate sensor is~~becomes~~ slow due to the relatively large heat capacities of the capillary tube and the resistance wire forming the~~a~~ heater.

[0004] On the other hand, along with ~~the~~ development in recent years of~~in~~ the so-called "micro-machine" technologies~~in recent years~~, the development and utilization of the latter, or of a silicon-made ultra-small sized thermal-~~-~~type mass flow rate sensor, have been widely under way. It has become popular, not only in the chemical-related fields, but also in ~~the~~ industrial manufacturing fields such

as the~~an~~ automobile industry and the like, because~~due to the reason that~~ a silicon-made ultra-small sized thermal-type mass flow rate sensor can be manufactured by~~under~~ a single processing, thus reducing unevenness in properties among ~~the~~ products. Furthermore,~~, and achieving the~~ extremely fast response speed as a sensor can be achieved by making heat capacities small by downsizing the sensor, all of which are regarded as desired~~excellent~~ characteristics of a~~the~~ sensor.

[0005] However, it is noted that there exist many problems to be solved with ~~said~~ silicon-made ultra-small sized thermal-type mass flow rate sensors. Among other things, corrosion resistance is one problem that is urgently needed to be solved~~urgently~~.

~~-2-~~

That is, a silicon-made ultra-small sized mass flow rate sensor employs silicon as a constituent component to form gas contacting faces. Therefore, a fundamental difficulty encountered with conventional sensors is that these silicone gas contacting faces~~it~~ can be easily corroded by fluids of the halogen family and the like.

[0006] Furthermore, organic materials such as ~~an~~ epoxy resin, an O-ring and the like, are used as sealing materials for the mass flow rate sensor, thus making the emission of particles, or the occurrence of an~~the~~ outside leak, unavoidable. Consequently, such sensors cannot be employed~~Accordingly, it becomes unable that the sensor is applied~~ for the gas supply line, and the like, in semiconductor manufacturing facilities.

[0007] Furthermore, ~~there exists~~ another problem exits with the mass flow rate

sensor, namely~~that is~~, fluctuation in detecting values of the mass flow rate sensor occurs when the pressure of the fluid to be measured changes, or there may be distortion of the sensor itself caused by a~~the~~ mechanical tightening force (or thrust) that occurs when the~~a~~ mass flow rate sensor is fitted to the gas supply line. These problems ~~, which will be the~~ cause ~~of~~ unevenness in ~~the~~ detecting values of the mass flow rate sensor.

[0008] So far, v~~V~~arious techniques have been developed ~~so far~~ to solve these difficulties with the afore-mentioned silicon-made ultra-small sized thermal-~~-~~type mass flow rate sensor.

————For example, with the devices of TOKU-KAI No. 2001-141540 and the TOKU-KAI No. 2001-141541 and the like, there is provided a temperature resistance layer E_6 on the outermost layer of a film E, formed on the upper face of the frame D made from a silicon substrate A, as shown in Figure 20, to enhance stability of the film E. As shown in~~With~~ Figure 20, E_1 to ~~~~~ E_3 designate a silicon oxide layer forming~~to form~~ a film –

~~-3-~~

E, E_4 designates a silicon nitride layer, E_5 designates a platinum layer, and C designates~~a~~ lead connecting hardware.

[0009] As stated above, with the afore-mentioned silicon-made ultra-small sized thermal-~~-~~type mass flow rate sensor, as shown in Figure 20, there is formed a silicon nitride layer E_4 on the lower face side of the frame D, or a temperature resistant layer E_6 consisting~~ed~~ of a silicon nitride layer, to enhance ~~the~~ water resistance and moisture resistance of the film E.

[0010] Patent Document 1: TOKU-KAI No.2001-141540 Public Bulletin

Patent Document 2: TOKU-KAI No.2001-141541 Public Bulletin

~~Disclosure of the Invention~~

Objects of the Invention

[0011] The present invention ~~is to~~ solves the afore-mentioned problems with ~~the~~ conventional mass flow rate sensors, such as (1) ~~one~~ that unevenness in property among products is caused and the response speed is~~becomes~~ low when~~with~~ a capillary thermal type mass flow rate sensor is used, and (2) ~~the other~~ that the emission of -particles, the occurrence of outside leaks, and the like, cannot be avoided when~~with~~ a silicon-made ultra-small sized thermal--type mass flow rate sensor is used because such sensors are~~in addition that it is~~ less corrosion-resistant, and also because~~that~~ unevenness in detecting values of the mass flow rate occurs due to changes in ~~the~~ pressure of the fluid to be measured or changes in the fitting mechanism of the sensor. It is a primary object of the present invention to provide a corrosion-resistant metal made sensor for fluid and a fluid supply device for which the sensor is employed, and (a) to make it possible that ultra-small sized products with ~~the~~ uniform quality can be ~~is~~ manufactured -

~~-4-~~

by using micro-machine technologies;~~,~~ (b) further, to make it possible that unevenness caused by changes in ~~the~~ detecting values of the fluid pressure is automatically adjusted;~~,~~ (c) to make a sensor of the invention~~it~~ equipped with excellent corrosion resistance;~~,~~ (d) to make it possible that a sensor, in accordance with the invention,~~it~~ achieves ~~the~~ high response speed and to make the sensor~~it~~ particle-free;~~,~~ (e) to make the sensor~~it~~ outside-leakless;~~,~~ and (f) to

make it~~It~~ possible that both mass flow rate and fluid pressure are detected by the sensor.

Means to Solve the Objects

[0012] Inventors of the present invention have realized~~come to an idea~~ that by employing micro-machine technologies to form 2 resistance thermometer sensors, a heater, a lead wire to connect elements, and the like, required for a mass flow rate sensor part and a strain sensor element, a lead wire and the like, required for a pressure sensor part by using a thin film body on a~~the~~ substrate made of corrosion-resistant metal, such as stainless steel and the like, can be made so that (a) unevenness in quality of the sensor for fluid is prevented and corrosion resistance and responsivity are enhanced, (b) a~~being~~ particle-free and outside leakless sensor is~~are~~ achieved, (c) unevenness caused by changes in ~~the~~ detecting values of ~~the~~ fluid pressure is automatically adjusted, and (d) ~~the~~ fluid pressure can be monitored through the pressure sensor part. A~~, and a~~ prototype of a sensor for fluid, equipped with the mass flow rate sensor part and the pressure sensor part, in accordance with the present invention, has been built and ~~the~~ operation tests have been performed thereon~~repeated based on said idea~~.

[0013] The present invention has been created based on the afore-mentioned idea and the results of~~n~~ various tests. The present invention, in accordance with a first embodiment~~as claimed in~~

~~Claim 1~~, is characterized by a corrosion-resistant metal made sensor constructed so~~that it is so constituted~~ that the mass flow rate and pressure of

fluid are measured by its being equipped with a mass flow rate sensor part 3 comprising a corrosion-resistant substrate 2, and a thin film forming a temperature sensor 3a, and a heater 3b installed on the back face side of the fluid contacting surface of the~~said~~ corrosion-resistant substrate 2~~-~~, and a pressure sensor part 4 comprising a thin film forming a strain sensor element 4a mounted on the back face side of the fluid contacting surface of the metal substrate 2.

[0014] The present invention, in accordance with a second embodiment, modifies the first embodiment~~as claimed in Claim 2 according to the invention as claimed in Claim 1 is so constituted~~ so that a corrosion-resistant metal substrate 2 is fitted into the mounting groove 10a of a corrosion-resistant metal made sensor base 10 in a state in which its fluid contacting surface is exposed outwardly, and the peripheral edge of the corrosion-resistant metal substrate 2 is hermetically welded to the sensor base 10.

[0015] The present invention, in accordance with a third embodiment, modifies the first and second embodiments~~ as claimed in Claim 3 according to the invention as claimed in Claim 1 or Claim 2 is so made~~ so that the output drift to the pressure of the mass flow rate sensor part 3 is corrected by the output of the pressure sensor part 4.

[0016] The present invention, in accordance with a fourth embodiment,~~ as claimed in Claim 4~~ is ~~so~~ made so that a thin film F in accordance with the first, second or third embodiments~~Claim1, Claim 2 or Claim 3~~, is provided~~constituted~~ with an insulating film 5 formed on the back side of the fluid contacting surface of the corrosion-resistant metal substrate 2, a metal film M that~~which~~ forms a

temperature sensor 3a, a heater 3b and a strain sensor element 4a thereupon, and a protection film 6 to cover the insulating film 5 and the metal film M.

~~-6-~~

[0017] The present invention, in accordance with a fifth embodiment~~as claimed in Claim 5~~, is ~~so~~ made so that a corrosion-resistant metal made sensor for fluid, in accordance with one of the first four embodiments,~~stipulated in one of Claims 1 to 4~~ is mounted on a fluid controller in order that the flow rate and pressure can be appropriately checked at the time of ~~the~~ fluid control.

[0018] The present invention, in accordance with a sixth embodiment~~as claimed in Claim in Claim 6~~, is ~~so constituted~~ constructed so that a sensor base 10 of the corrosion-resistant metal made sensor S for fluid, in accordance with the second embodiment,~~stipulated in Claim 2~~ is positioned inside the fluid passage 21b of a body 21 equipped with the afore-mentioned fluid passage 21b for communicating between the flow-in inlet 21a for the fluid G and the flow-out outlet 21c for the fluid by installing a metal gasket 27, in order that hermeticity between the body 21 and the sensor base 10 is held by thrusting the metal gasket 27 through the mediation of the afore-mentioned sensor base 10, and at the same time stiffness of the structural component directly above the metal gasket 27 is relatively raised to hold the afore-mentioned hermeticity~~is relatively raised~~, thus suppressing ~~the~~ strain of the mass flow rate sensor part 3 and the pressure sensor part 4 caused by thrusting the~~said~~ metal gasket 27.

Effects of the Invention

[0019] In accordance with the present invention, a mass flow rate sensor is

manufactured by applying micro-machine technologies, as in the case of a~~the~~ conventional silicon made ultra-small sized mass flow rate sensor, thus reducing~~enabling to reduce~~ unevenness in quality among products to a minimum. In addition, a corrosion-resistant metal substrate, for example, the substrate made with ~~the~~ SUS316L used for the sensor substrate, is processed to make the substrate~~it~~ a thin plate, and -

~~-7-~~

a resistance wire and the like are made to be thin films so as~~,~~ to make the heat capacity of the sensor part extremely small, thus increasing the response speed of the sensor remarkably.

[0020] Also, in accordance with the present invention, all the gas contacting faces are constituted of a corrosion-resistant metal, and the sensor part and the sensor base are assembled by welding, and a metal gasket sealing is employed to mount the gas contacting faces and sensor part and sensor base~~them~~ on a valve body and the like, thus making the sensor~~enabling to achieve to make it~~ corrosion-free, particle free and outside leak-free.

[0021] In addition, in accordance with the present invention, a~~q~~ mass flow rate sensor and a pressure sensor part are concurrently formed on the corrosion-resistant metal substrate, thus making it possible to adjust the amount of changes (the drift amount) of the mass flow rate due to changes of the fluid pressure, by using ~~the~~ detecting values in the pressure sensor part, to allow accurate detection of the mass flow rate and also ~~enable~~ to output ~~the~~ detected values of the pressure to the outside, when necessary.

Brief Description of the Drawings

[0022] Figure 1 is a plan schematic view of a~~the~~ sensor part of a corrosion-resistant metal made thermal-type mass flow rate sensor according to the present invention.

Figure 2 is a cross-sectional schematic view taken along line A-A of Figure 1.

Figure 3 is an explanatory drawing of the operating principle of a corrosion-resistant metal made thermal-type mass flow rate sensor, according to the present invention.

~~-8-~~

Figure 4 includes~~is~~ explanatory drawings illustrating~~to illustrate~~ the manufacturing process of a sensor part, where (a) pertains to~~is~~ the preparation process of a stainless steel thin plate, (b) pertains to~~is~~ the formation process of an insulation film 5, (c) pertains to~~is~~ the formation process of a Cr/Pt/Cr film (a metal film M), (d) pertains to~~is~~ the formation process of a protection film 6, (e) pertains to~~is~~ the formation process of an electrode insertion hole, (f) pertains to~~is~~ the etching process of the back side of the~~a~~ stainless steel thin plate, and (g) pertains to~~is~~ the separation etching process of ~~a~~ sensor part 1.

Figure 5 is a sectional schematic view illustrating~~to illustrate~~ an example of a corrosion-resistant metal made fluid sensor~~ for fluid~~.

Figure 6 is a block diagram of a signal detecting circuit, for detecting the mass flow rate of a sensor for fluid, according to the present invention.

Figure 7 is a graph illustrating~~diagram to illustrate~~ the relationship between ~~the~~ fluid pressure and the fluid sensor output/~~the~~ bridge circuit output of

the temperature sensor.

Figure 8 includes graphs illustrating~~is a diagram to illustrate~~ various characteristics of a sensor part, according to the present invention, where (a) shows the relationship between ~~the~~ temperature of a heater and the resistance value of the temperature detecting resistance, (b) shows the relationship between ~~the~~ current of the~~a~~ heater and the resistance value of the temperature detecting resistance, and (c) shows the relationship between ~~the~~ gas flow rate and ~~the~~ sensor output.

Figure 9 is a graph illustrating~~a diagram to illustrate the~~ flow rate characteristics of a sensor when ~~the~~ compensation is performed against ~~the~~ pressure changes by using a pressure sensor part 4.

~~9~~

Figure 10 is a diagram illustrating~~to illustrate~~ one example of ~~a~~ flow rate response characteristics of a sensor for fluid, in accordance with~~with regard to~~ the present invention.

Figure 11 is a flow block diagram of a measuring circuit used for measuring ~~the~~ flow rate characteristics of a sensor S for fluid, in accordance with ~~with regard to~~ the present invention.

Figure 12 is a flow block diagram of a measuring circuit used for measuring_ ~~the~~ flow rate characteristics to ~~the~~ supply pressure changes of a sensor S for fluid, in accordance with~~with regard to~~ the present invention.

Figure 13 is a diagram illustrating ~~illustrates the~~ flow rate characteristics, at the time of ~~the~~ supply pressure changes, of a sensor S for fluid in accordance

with~~according to~~ the present invention as measured using~~with~~ the measuring circuit of~~in~~ Figure 12.

Figure 14 is a cross-sectional view illustrating~~to illustrate~~ an example of an~~the~~ assembly drawing of a sensor for fluid, according to the present invention.

Figure 15 is a cross-sectional view illustrating another~~to illustrate the other~~ example of an ~~the~~

assembly drawing of a sensor for fluid, according to the present invention.

Figure 16 is a cross-sectional view illustrating the assembly drawing of yet~~to illustrate~~ another example of ~~the assembly drawing of~~ a sensor for fluid according to the present invention.

Figure 17 is a plan view illustrating another~~to illustrate the other~~ example of an~~the~~ assembly of a sensor for fluid, according to the present invention.

Figure 18 is a cross-sectional view taken along line B-B of Figure 17.

Figure 19 is a side view of the assembly of Figure 17.

Figure 20 is a cross-sectional view illustrating~~to illustrate~~ the outline of a~~the~~ conventional silicon made ultra-small sized thermal-~~-~~type mass flow rate sensor.

~~-10-~~

List of Reference Characters and Numerals

[0023] S Corrosion-resistant metal made sensor for fluid

F Thin film

M_1 Metal film that~~which~~ forms a mass flow rate sensor part

M_2 Metal film that~~which~~ forms a pressure sensor part

W Corrosion-resistant metal material

G Gas to be measured

1 Sensor part

2 Corrosion-resistant metal substrate

3 Mass flow rate sensor part

3a Temperature sensor

$3a_1$, $3a_2$ Temperature detecting resistances

3b Heater

4 Pressure sensor part

4a Strain sensor element

5 Insulation film

6 Protection film

6a Protection film for the mass flow rate sensor part

6b Protection film for the strain sensor part

7 Electrode insertion hole

9a・9b Resists

10 Sensor base

10a Mounting groove

~~-11-~~

11 Heater driving circuit

12a Pressure offset adjustment circuit

12b Mass flow rate offset adjustment circuit

13 Offset adjustment circuit (for fine tuning)

14 Gain adjustment circuit

15a,15b Differential amplifying circuits

16 Mass flow rate output terminal

17 Fluid pressure output terminal

$4a_1$ · $4a_2$ Strain sensor elements

18 Signal treatment circuit

19 Multiplying treatment circuit

20 Joint part

21 Body

22 Sensor base presser

23 Wiring substrate presser

24 Wiring substrate

25 · 26 Guide pins

27 Metal gasket

28 Rubber sheet

29 Lead pin

30 Lead wire (a gold wire)

31 Body

32 Pressure detector

~~-12-~~

33 Control Valve

34 Piezo-electric valve driving device

35 Orifice

36 Filter

37 Relay substrate

38 Bearing

39 Fixture screw hole

40 He gas source

41 Pressure adjuster

42 Pressure type flow rate controller

43 Diaphragm vacuum pump

44 Driving circuit for the sensor S for fluid

45 Oscilloscope

46 Signal transmitter

47 3-way switching valve

48 Mass flow meter

$P_1 \cdot P_2$ Pressure gages

49 Secondary side pipe passage of the pressure type flow rate controller (inner capacity of 15cc or 50cc)

50 Pressure adjusting valve

S_0 Flow rate output of the sensor S for fluid

F_0 Flow rate output of the pressure type flow rate controller

M_0 Flow rate output of the mass flow meter

~~-13-~~

PT Output of the secondary side pressure gauge

51 Fluid flow-in inlet

52 Fluid flow-out outlet

~~Best Mode of Carrying Out the Invention~~

Detailed Description of the Invention

[0024] [Preferred Embodiment 1 of the Corrosion-Resistant Metal Made Sensor for Fluid]

An~~The~~ embodiment in accordance with the present invention is described as follows~~hereunder~~ with reference to the drawings.

Figure 1 is a plan schematic view of ~~the~~ sensor part 1, which is an essential part of a corrosion-resistant metal made thermal-type mass flow rate sensor according to the present invention. Figure 2 is a cross-sectional schematic view taken on line A-A of Figure 1.

[0025] S~~aid s~~ensor part 1 comprises a thin corrosion-resistant metal substrate 2, an insulation film 5 formed on the upper face of the substrate 2, a mass flow rate sensor part 3 and a pressure sensor part 4 formed on the upper face of the insulation film 5, and a protection film 6, and the like, formed on the mass flow rate sensor part 3, the pressure sensor part 4, and the like.

Also, the afore-mentioned mass flow rate sensor part 3 comprises a temperature sensor 3a, a heater 3b and the like, and the afore-mentioned pressure sensor part 4 comprises a strain sensor element 4a, and the like, respectively.

Furthermore, as shown in Figure 2, a thin film F is formed with a metal film M that~~which~~ forms an insulation film 5, and with temperature detecting resistances $3a_1$, $3a_2$ of the temperature-

~~-14-~~

sensor 3a, a heater 3b, an electric conductive lead part (not illustrated), a strain sensor element 4a and the like, and a protection film 6 on the upper face side (or on the back face side of the fluid contacting surface) of the corrosion-resistant

metal substrate 2. And, an electrode insertion hole 7, with an approximate size, is formed on the afore-mentioned protection film 6 by an~~the~~ etching process.

[0026] A gas G to be measured flows in the direction of the arrow, shown in Figure 2, along the corrosion-resistant metal substrate 2 on the under face side (or the surface side of the fluid contacting surface) of the sensor part 1 as shown in Figure 2 and Figure 3. When this happens, some of the heat of~~quantity contained with~~ the gas G is given to the corrosion-resistant metal substrate 2, thus resulting in shifting of~~that~~ the temperature distribution Tt of the corrosion-resistant metal substrate 2 ~~shifts~~ from the temperature distribution To, where there is no flow of ~~the~~ gas G, to the temperature distribution Tt as shown in Figure 3.

[0027] As stated above, changes in the temperature distribution of a corrosion-resistant metal substrate 2 caused by the flow of ~~the~~ gas G are presented as changes in ~~the~~ voltage values at ~~the~~ both ends of the temperature detecting resistances $3a_1$, $3a_2$ through ~~the~~ mediation of changes in the resistance values of the temperature detecting resistances $3a_1$, $3a_2$, which form the temperature sensor 3. Thus, the mass flow rate of ~~the~~ gas G can be known by detecting ~~the~~ changes in the voltage values as a differential output. The above stated operating principle of the thermal type mass flow rate sensor is identical to~~with~~ that of ~~the~~ publicly known silicon made thermal-type mass flow rate sensors. Therefore, a~~the explanation in~~ detailed explanation is omitted herewith.

~~-15-~~

[0028] Similarly, the pressure of the gas G, to be measured, is continuously

detected through ~~the~~ mediation of ~~the~~ output of the strain sensor element 4a, and the pressure changes of ~~the~~ gas G are detected as ~~the~~ output changes of the strain sensor element 4a.

As described later, because~~since the~~ output of the mass flow rate sensor part 3 changes roughly in proportion to ~~the~~ pressure of the gas G to be measured, a~~the~~ detection value of the detected mass flow rate at the mass flow rate sensor part 3 is corrected by using a~~the~~ detected pressure value at the~~said~~ pressure sensor part 4.

[0029] The response speed and sensor sensitivity of the mass flow rate sensor part 3 are affected by the corrosion-resistant metal material W, which forms the afore-mentioned sensor part 1, because the thermal capacity of the sensor part 1 changes~~is changed~~ with its thickness. Referring to Figure 1 and Figure 2, in accordance with the present embodiment, a stainless steel thin plate (SUS316L) of less than 150 μ m thick is used. It is possible to raise~~that~~ the response speed and sensor sensitivity ~~are raised~~ by making the thickness less than 150 μ m, thus the heat capacity of the sensor part 1 is also~~being~~ smaller. However, it goes without saying~~there is no need to say~~ that the thickness could be more than 150 μ m if ~~the~~ sufficient response speed and sensor sensitivity are assured.

[0030] As described later, the afore-mentioned insulation film 5 is an oxidized film having a~~with~~ thickness of 1.2 μ m to ~~~~1.8 μ m, formed by the so-called "CVD method" (Chemical Vapor Deposition method). In accordance with this~~With the present~~ embodiment, a 1.5 μ m thick SiO_2 film, formed by the CVD (Chemical Vapor Deposition) method, has been used for thee insulation film 5.

~~-16-~~

[0031] The afore-mentioned temperature detecting resistances $3a_1$, $3a_2$ and heater 3b are made from a metal film M_1 formed by using a~~the~~ mask pattern (not illustrated) for the mass flow rate sensor on the afore-mentioned insulation film 5. In accordance with~~With~~ the present embodiment, the temperature detecting resistances $3a_1$, $3a_2$, and heater 3b, and the like, are made from a metal film formed by a Cr/Pt/Cr film (with thickness of 10/100/10 μm, respectively) that is~~being~~ laminated, in order, by the vapor deposition method.

[0032] Similarly, a strain sensor element 4a is made from a metal film M_2 formed by using a~~the~~ mask pattern (not illustrated) for the strain sensor part on the afore-mentioned insulation film 5. In accordance with~~With~~ the present embodiment, the strain sensor element 4a, and the like, are made from a metal film M_2 formed by Cr/Cr-Ni/Cr film (with thickness of 10/100/10 μm, respectively) that is~~being~~ laminated, in order by, the vapor deposition method.

[0033] The afore-mentioned protection film 6 is a film body to cover the upper part of the temperature detecting resistances $3a_1$, $3a_2$, the heater 3b, the strain sensor element 4a, and the like. In accordance with~~With~~ the present embodiment, the 0.4 to ~~∼~~0.7 μm thick SiO_2 film (the mass flow rate sensor part 3 and the pressure sensor part 4), formed by the CVD method, is~~has been~~ used. Also, the~~said~~ protection film 6 is provided with a suitably shaped electrode insertion hole 7, made by a~~the~~ plasma etching method, to draw out an electrode rod, and the like, through the~~said~~ electrode insertion hole 7.

[0034] The back face side of the~~a~~ corrosion-resistant metal substrate 2, which forms ~~a~~ sensor part 1, is finished with a thickness of less than 150 μm.

~~-17-~~

The sensor part 1 is eventually separated from the corrosion-resistant metal material W by a~~the~~ method of the so-called "through-etching processing." As described later, the separately formed sensor part 1 is hermetically fixed to the corrosion-resistant metal made flow rate sensor base 10 by ~~the~~ laser welding, or the like, so that the corrosion-resistant metal made sensor S for fluid, according to the present invention, having~~with~~ the structure as shown in Figure 5 is so constituted. In Figure 5~~Here~~, 10a is a mounting groove provided on the sensor base 10.

[Work Process of the Sensor Part]

[0035] Next, a~~the~~ manufacturing work process of the mass flow rate sensor part 3, which forms the afore-mentioned sensor part 1, is explained as follows~~hereunder~~.

Figure 4 provides~~is~~ explanatory drawings showing~~to show~~ the manufacturing process of the mass flow rate sensor part 3, and pressure sensor part 4, which form the sensor part 1 in accordance with the present invention.

[0036] First, as shown in Figure 4(a), a stainless steel made thin plate (SUS316L) with appropriate dimensions, for example, of the diameter of 70 to ~~∼~~150mm ϕ and a~~the~~ thickness of less than 150 μm, is prepared for the corrosion-resistant metal material. It goes without saying ~~(Figure 4(a)) There is no need to say~~ that a thin metal plate (for example,~~,~~ an austenitic steel plate made of a Cr-Ni alloy) other than a thin stainless steel plate can be employed as~~for~~ the corrosion-resistant metal material W.

[0037] Then, as shown in Figure 4(b), a SiO_2 film 5 (an insulation film) with a thickness of approximately 1.5 μm is formed on the outer back face of the

afore-mentioned prepared stainless steel thin plate by a plasma CVD device (Plasma-Enhanced Chemical Vapor Deposition Device) for which ~~the~~ TEOS (Tetr~~r~~a-Ethoxy-Silane) is used.

~~-18-~~

~~(Figure 4(b))~~

[0038] After that, as shown in Figure 4(c), there are formed patterns of temperature detecting resistances $3a_1$, $3a_2$, a heater 3b, and the like, made from a metal film M_1 formed by a~~the~~ Cr/Pt/Cr film (with thickness of 10/100/10 μm, respectively) by employing an electronic beam heating-type vapor deposition device and ~~a~~ photo-mask patterns (not illustrated) for forming a mass flow rate sensor part 3 on the afore-mentioned SiO_2 film 5. ~~(Figure 4(c))~~

[0039] After the~~a~~ metal film M_1, which forms the afore-mentioned mass flow rate sensor part 3, has~~having~~ been formed, then patterns of a strain sensor element 4a, and the like, made from a~~the~~ Cr/Cr-Ni alloy/Cr film (with thickness of 10/100/10 μm, respectively) are made on the SiO_2 film 5, as shown by Figure 4(d), with a metal film M_2 by using ~~the~~ photo-mask patterns (not illustrated) for forming the pressure sensor part 4 instead of the photo-mask patterns for forming the mass flow rate sensor part 3. ~~(Figure 4(d))~~

[0040] And then, a SiO_2 film (a protection film) 6, of thickness of approximately 0.5 μm, is formed on the temperature detecting resistances $3a_1$, $3a_2$ and heater 3b, which form the mass flow rate sensor part 3, and on the strain sensor element 4a, which forms the pressure sensor part 4. The protection film 6 is made through the processes of the afore-mentioned Figure 4(c) and Figure4(d), which utilize~~with~~ the plasma CVD device for which the afore-mentioned TEOS is

employed in accordance with ~~. (~~Figure 4(e).~~)~~

[0041] Then, on the afore-mentioned protection film 6~~, there~~ are made an electrode takeout hole (an electrode insertion hole 7) with a bore of 200 μm that is~~to be~~ used for the temperature detecting resistances $3a_1$, $3a_2$ and ~~a~~ heater 3b, and ~~-~~

~~-19-~~

also an electrode takeout hole (not illustrated), with a bore of approximately 100 μm, that is~~to be~~ used for the strain sensor element 4a. The electrode takeout holes are made by using ~~the~~ photo-mask patterns (not illustrated) to make an electrode insertion hole, in accordance with Figure 4(f), employing~~with~~ the plasma etching device that uses~~for which the~~ CF_4 gas~~ is used. (Figure 4(f))~~

[0042] Because~~Due to the reason that the~~ SUS316L or Cr has a high tolerance to the plasma of~~by the~~ CF_4 gas, etching ~~in~~ progress stops automatically upon completion of etching of the SiO_2 film 6~~ being completed~~. Accordingly, there is no danger at all that~~of the~~ so-called "over-etching" may occur~~being caused at all~~.

[0043] Lastly, after resists 9a, 9b have been~~being~~ coated, ~~a~~ sensor part 1 is detached from the material W by cutting through, in a circular shape, with the etching treatment using ~~the~~ ferric chloride solution ($FeCl_3$ · 40wt%).

[0044] The circular shaped sensor part 1, once separated from the material W, is fitted into the mounting groove 10a of the sensor base 10, formed in the shape as shown in Figure 5, and is welded and fixed hermetically to the sensor base 10 at~~by~~ the outer periphery part that is~~being~~ laser-welded. Thus, a corrosion-resistant metal made sensor S for fluid according to the present invention is constructed~~constituted~~.

[0045] Figure 6 is a block diagram of a signal detecting circuit for detecting a mass flow rate of the fluid sensor S, ~~for fluid~~ according to the present invention. The~~Said~~ signal detecting circuit comprises a sensor part 1 formed by a mass flow rate sensor part 3 and a pressure sensor part 4, a heater driving circuit 11, a pressure offset adjustment circuit 12a, a mass flow rate offset adjustment circuit 12b, an offset adjustment circuit (for fine tuning) 13, a gain adjustment circuit 14, differential amplifying circuits 15a, 15b, a mass flow rate output terminal 16, a ~~-~~

~~-20-~~

fluid pressure output terminal 17, a signal treatment circuit 18, a multiplying treatment circuit 19, and the like. As shown in~~With~~ Figure 6, $3a_1$ and $3a_2$ are temperature sensor elements, and $4a_1$ and $4a_2$ are strain sensor elements.

[0046] Referring to Figure 6, the~~a~~ mass flow rate sensor part 3 is heated by the operation of the~~a~~ heater driving circuit 11. When resistance values change with ~~the~~ temperature changes of the upstream side temperature detecting resistance $3a_1$ and the downstream side temperature detecting resistance $3a_2$, which form the temperature sensor element 3a of the mass flow rate sensor part 3, while the gas G to be measured passes through, these changes are inputted to the differential amplifying circuit 15b as ~~the~~ changes of voltage, and the differential amplifying output is outputted to the mass flow rate output terminal 16 through ~~the~~ mediation of the mass flow rate offset adjustment circuit 12b, the offset adjustment circuit 13, and the multiplying treatment circuit 19.

[0047] Because~~Due to the reason that~~ the corrosion-resistant metal substrate 2, which forms a sensor part 1 of the present invention, is made to be a thin film, the sensor part 1 strains with the gas pressure when~~while the~~ gas G passes

through, thus resulting in changes of resistance values of the temperature detecting resistances $3a_1$, $3a_2$ of the temperature sensor 3a, so as to make the bridge output of the temperature sensor 3a change~~d~~.

[0048] Figure 7 shows the relationship between ~~the~~ fluid pressure when ~~there is made~~ no adjustment is made with the pressure sensor part 4 (namely, the gain adjustment with ~~the~~ pressure offset adjustment circuit 12a, the adjustment with ~~the~~ offset adjustment circuit 13 by ~~the~~ output from the signal treatment circuit 18, ~~-21-~~ and the gain adjustment with ~~the~~ gain adjustment circuit 14), and the mass flow rate output (the output mV of ~~the~~ output terminal 16) with the fluid sensor S ~~for fluid~~ according to the present invention. C~~The c~~urves A, B and C show the measured values (in the case of a current value of 5mA to the temperature detecting resistances $3a_1$, $3a_2$) with three samples.

[0049] In either case of when the~~a~~ heater 3b is operated or the heater 3b is not operated, experimentation has confirmed~~it has been confirmed with the experiment~~ that ~~the~~ output of the sensor S changes with ~~the~~ change~~s~~ of ~~the~~ fluid pressure. Or~~, or~~ even with the same heater operating current, experimentation has confirmed that the amount of ~~the~~ change in the resistance values, due to ~~the~~ fluid pressure P of the upstream side temperature detecting resistance $3a_1$ and the downstream side temperature detecting resistance $3a_2$, differ.

[0050] As stated above, when an ordinary resistance bridge circuit is employed, ~~there occurs~~ a problem occurs in that ~~the~~ output of the sensor part 1 changes with the generation of strain. However, using~~with~~ the signal detecting circuit according to the present invention, the sensor S~~it~~ is ~~so~~ constituted so that the

rate of amplification of voltage values, outputted from the upstream side temperature detecting resistance $3a_1$ and the downstream side temperature detecting resistance $3a_2$ and the offset, are fine-tuned through the mediation of ~~the~~ strain sensor elements $4a_1$, $4a_2$, the pressure offset adjustment circuit 12a, the signal treatment circuit 18, and the like, with the output from the pressure sensor part 4. Thus,~~, thus~~ changes in the output voltage values of the temperature detecting resistances $3a_1$, $3a_2$, produced by the application of the fluid pressure P, is ~~being~~ cancelled out by adjusting the afore-mentioned amplification rate and the offset.

~~-22-~~

As a result, it ~~has~~ becomes possible that output changes of the sensor part 1, by the gas pressure, are~~is~~ perfectly constrained, thus making it possible to accurately detect~~that the~~ mass flow rate~~ is accurately detected~~.

[0051] Figure 8 illustrates characteristics of a sensor S for fluid according to the present invention. Figure 8(a) shows the relationship between the temperature of ~~a~~ heater 3b and the resistance value, Figure 8(b) shows the relationship between the current value of ~~the~~ heater 3b and the resistance value, and Figure 8(c) shows the relationship between the gas flow rate (SCCM) and the detected output value (V), respectively.

[0052] The resistance value of the heater 3b of the temperature sensor 3a, used to measure various characteristics in Figure 8, is approximately 2.4kΩ, and the resistance values of the temperature detecting resistances $3a_1$, $3a_2$ are each 2.0kΩ (both having identical values). 10mA current was passed to the heater 3b, and 1.2mA current was passed to the temperature detecting

resistances $3a_1$, $3a_2$. Also, the fluid pressure was~~is~~ kept at a specific value of 100kPaG.

[0053] Furthermore, ~~the~~ changes in the output value of the sensor part 1 were~~was~~ approximately 1.0V when the gas flow rate was made to change~~d~~ in the range of 0 to ~~≈~~100SCCM. (However, the output value was amplified 500 times with the OP amplifier.)

[0054] In addition, because the output value of the sensor part 1 depends on the clearance (the height of the flow passage) between the flow rate sensor base 10 of the fluid sensor S ~~for fluid~~ and the fluid passage shown in Figure 14, as described ~~,~~later, the range capable for measuring~~to measure a~~ flow rate can be appropriately switched by adjusting the afore-mentioned height of the flow passage.

~~-23-~~

[0055] Figure 9 illustrates the relationship between ~~the~~ fluid flow rate and ~~the~~ sensor output at a~~the~~ time when the pressure sensor part 4 is operated and ~~the~~ adjustment is performed by the pressure sensor part 4 as shown in~~in the afore-shown~~ Figure 6. As shown in~~With~~ Figure 9, Curve A_1 shows the case when the pressure sensor part 4 is not operated with a~~the~~ fluid pressure of 100KPaG (namely, Curve C as shown in ~~the afore-shown~~ Figure 8). ~~,~~ Curve A_2 shows the case when the fluid pressure is raised to 150KPaG (namely, the pressure sensor part 4 not being operated, and other conditions for experiments are same as those of Curve A_1). ~~, and~~ Curve A_3 shows the case when the pressure sensor part 4 is operated with fluid pressure of 150KPaG (other conditions for experiments are same as those of Curve A_1) ~~respectively~~. In

accordance wWith the sensor S for fluid, according to the present invention, testingit has been confirmesd that even when the fluid pressure changes from 100KPaG to 150KPaG, the changes in the flow rate-output characteristics are completely prevented by operating the pressure sensor part 4.

[0056] Figure 10 shows one example of the flow rate response characteristics of the sensor S for fluid, and also shows characteristics in the case when the gas flow rate is set at 0 to ~100SCCM. As shown by

With Figure 10, Curve SA demonstratesis the flow rate response characteristics of the sensor S for fluid according to the present invention, and the lateral axis is graduated in 250msec blocks. Curve SF illustrates the flow rate response characteristics under the same conditions as those of the mass flow rate sensor with athe conventional pressure type flow rate controller.

Figure 11 is a flow block diagram of the measuring circuit used for -

-24-

measuring the relationship, shown in (Figure 9), between the gas flow rate (SCCM) and the detected output value (V) of the afore-mentioned fluid sensor S for fluid according to the present invention. Helium (He) gas is supplied from the He gas source 40 to the pressure type flow rate controller 42 through the pressure adjuster 41, and the exhausted flow rate is measured with the pressure type flow rate controller 42 while Heit is exhausted by the diaphragm vacuum pump 43.

[0058] The sensor S for fluid, according to the present invention, which is a sensor to be testede measured, is fitted to the primary side flow passage of the pressure type flow rate controller 42.

As shown in~~With~~ Figure 11, 44 designates a driving circuit for the sensor S for fluid (a flow rate sensor), 45 designates an oscilloscope, and 46 designates a signal transmitter.~~,~~ The flow rate output S_0 of the sensor S for fluid is inputted to the oscilloscope 45, and is contrasted ~~put in a contrast~~ with the flow rate measurement value F_0 from~~by~~ the pressure type flow rate controller 42.

[0059] Figure 12 is a flow block diagram of the measuring circuit used when ~~the~~ supply pressure of the afore-mentioned sensor S for fluid, according to the present invention, changes. As shown in

~~With~~ Figure 12, 47 designates a 3-way switching valve, 48 designates a mass flow meter, 49 designates the secondary side pipe passage (with the inner capacity of 15cc or 50cc), 50 designates a pressure adjusting valve (the degree of opening so adjusted that P_2 becomes 100Torr at the He flow rate of 20SCCM), and P_1, P_2 designate pressure gages.

[0060] When the measurement is conducted, the pressure of the He gas supplied to the mass flow meter 48, and to the sensor S for fluid (a product of the

~~-25-~~

present invention・a sensor to be measured) and to the pressure type flow rate controller 42 is made to change~~d~~ by opening/closing the~~a~~ 3-way switching valve 47.

The secondary pipe passage 49, of the pressure type flow rate controller 42, is ~~so~~ set so that its inner capacity is 15cc (or 50cc). And, the secondary side Pressure P_2 is ~~so~~ adjusted by the pressure adjusting valve 50 so that the pressure P_2 is~~becomes~~ 100Torr when the He gas flow rate is 20SCCM during the full load operation of the vacuum pump 43.

———The detected flow rate S_0 of the sensor S~~-for fluid~~, the detected flow rate M_0 of the mass flow meter 48, the detected flow rate F_0 of the pressure type flow rate controller 42, and the pressure measurement values P_1, P_2, respectively, are inputted to and recorded by~~r respectively to~~ the oscilloscope.

[0061] Figure 13 shows ~~the~~ measurement results obtained with the afore-mentioned measurement circuit shown in Figure 12. The state of changes in the detected values F_0, P_2, S_0, M_0 is shown at the time when the supply pressure is made to change~~d~~ from 200KPa・abs to 150KPa・abs. It is revealed, from Figure 13, that when the detected value S_0 of the flow rate of the sensor S for fluid, according to the present invention, is compared with the detected value M_0 of the flow rate of the mass flow meter 48, both detected values S_0 and M_0 of the flow rate (flow rate signals) keep up with the changes in~~of~~ ~~the~~ supply pressure

[Embodiment 1 of the Fluid Supplier]

[0062] Figure 14 shows one example of a~~the~~ fluid supplier equipped with a sensor S for fluid, according to the present invention. It also shows a state of the sensor S for fluid that is~~being~~ fitted to the joint part 20 mounted on the gas flow -

~~-26-~~

passage. As shown in~~With~~ Figure 14, 21 designates a body of the joint part 20, 22 designates a sensor base presser, 23 designates a wiring substrate presser, 24 designates a wiring substrate, 25 designates a guide pin, 26 designates a guide pin, 27 designates a metal gasket, 28 designates a rubber sheet, 29 designates a lead pin, and 30 designates a lead wire (a gold wire).

The afore-mentioned guide pins 25, 26 are used for positioning the mass flow rate sensor S when it is fitted to the inside of the body 21. Hermeticity~~eremeticity~~ between the sensor base 10 and the body 21 is maintained by~~with~~ the metal gasket 27.

[0063] While the fluid gas G flowes~~d~~ in from the fluid flow-in inlet 21a and passes through a fluid passage 21b, the~~its~~ mass flow rate of gas G is detected by~~with~~ the sensor part 1, and the fluid gas G flows outside via~~from~~ the fluid flow-out outlet 21c.

In accordance w~~W~~ith the present invention, there is no risk at all that the substrate 2 is corroded by~~with~~ the gas G, as occurs with ~~the case of the~~ conventional silicon made substrate, because the gas to be measured passes through sensor S while contacting with ~~the~~ SUS316L made substrate 2.

[Embodiment 2]

[0064] Figure 15 shows the case where~~that~~ the sensor S for fluid, according to the present invention, is fitted to the main body part of the pressure type flow rate controller. As shown in~~With~~ Figure 15, S designates a fluid sensor~~ for fluid~~, 31 designates a body, 32 designates a pressure detector, 33 designates a control valve, 34 designates a Piezo-electric valve driving device, 35 designates an orifice and 36 designates a filter.

[Embodiment 3]

[0065] Figure 16 shows an alternate~~the altered~~ fitting position of the sensor S for fluid

~~27~~

according to the present invention. However, it is substantially the same as that

in Figure 15.

Since the structure~~constitutions~~ of a pressure type flow rate controller and its main parts have been disclosed by, for example, Japanese Patent No.3291161, the TOKU-KAI-HEI No.11-345027 and others, ~~the~~ explanation of this structure is omitted here~~with~~. The method of fitting a sensor S for fluid is the same in the embodiment of Figure 16 as that in Figure 14. Therefore, the above explanation is not repeated~~omitted herewith~~.

[Embodiment 4]

[0066] Figure 17 to Figure 19 show another~~the other~~ example in which a sensor S for fluid, according to the present invention, is fitted to a structural component, which constitutes a fluid controller. Figure 17 is a plan view, Figure 18 is a cross-sectional view, and Figure 19 is a side view.

As shown by~~With~~ Figure 17 to Figure 19, 37 designates a relay substrate, 38 designates a bearing, 39 designated a fixture screw hole for the sensor S, 51 designates a fluid flow-in inlet, and 52 designates a fluid flow-out outlet.~~,~~ The method of fitting a sensor S for fluid is the same as those described in Figure 14 and Figure 16. Therefore, an~~the~~ explanation of the fitting method described above is not repeated here~~is omitted herewith~~.

Feasibility of Industrial Use

[0067] The present invention is mainly used for detecting ~~the~~ mass flow rate and/or ~~the~~ pressure in ~~the~~ gas supply lines of~~with~~ semiconductor manufacturing facilities, various kinds of chemical product manufacturing equipment, and the like. However, the present invention~~it~~ can be also utilized for detecting ~~the~~ mass flow rate and pressure of a gas in the gas supply lines in many industrial fields.